Heat Capacity of Two-dimensional ^{3}He on Thin ^{4}He Films

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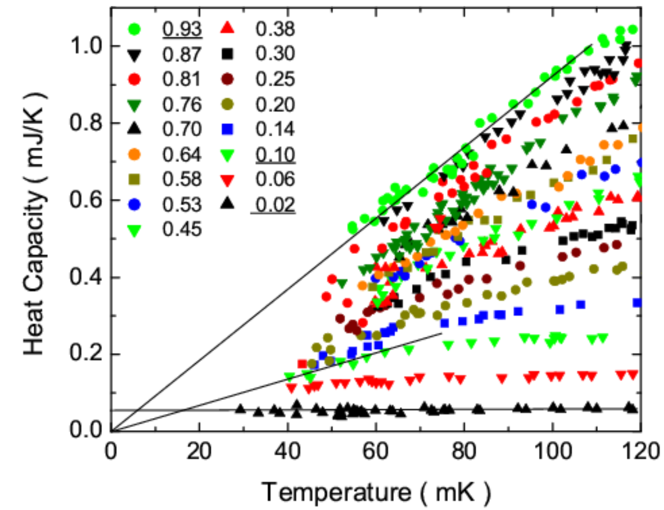
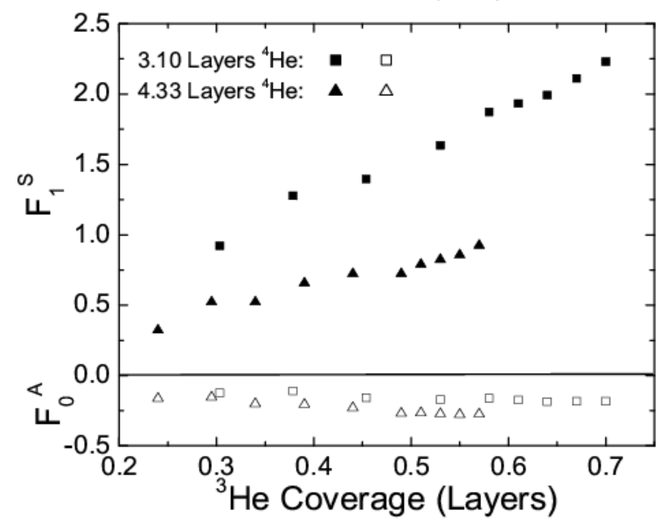
At low temperatures, ^{3}He atoms reside on the top of thin films of ^{4}He atoms. We have measured the heat capacity of this ^{3}He as a function of temperature and the amount of ^{3}He present (from 0.02 to 0.93 atomic layers) on films of ^{4}He of thickness 3.10 and 4.33 bulk-density atomic layers. The Fermi temperature of the system depends on ^{3}He coverage and because of this the heat capacity at low coverage is Boltzmann-like and at higher coverages shows degenerate behavior and is linear in the temperature. Combination of the results with our previous NMR measurements of the magnetization allow determination of the first two Fermi liquid parameters for the system, thus determining the interaction strength among the ^{3}He atoms.





Top figure: The heat capacity for various ^{3}He coverages for 3.10 layers of ^{4}He. Bottom Figure: the two lowest order Fermi liquid parameters for the ^{3}He.

H. Akimoto, J. Cummings and R.B. Hallock, J. Low Temp. Phys, December 2004 and (in preparation)

At extremely low temperatures, within 0.1 degree of absolute zero (roughly -460 degrees Fahrenheit) the world is a very different place. Surfaces at this temperature, when exposed to ordinary helium (the helium in the Goodyear blimp, termed helium-4, and denoted ^4He) adsorb that helium and the result is a film of helium on almost any such surface. If you picture paint on a surface, you have a rather good picture, expect that the helium-paint is special at these low temperatures – it is free to slide along the surface without any friction at all. If now the rare isotope of helium (termed helium-3 and denoted ^3He; rare indeed, only one atom of helium in 10,000,000 in the atmosphere is ^3He) is added to the system atom by atom at this low temperature, these ^3He atoms float on the ^4He much like ducks on a pond. And, they interact with the surface of the ^4He as well as with each other. These experiments tell us in some detail about how these atoms interact and the message tells us fundamental things that help us to understand how atoms interact with one another in more complex situations. This particular system is predicted by some to perhaps be able to undergo a very special type of interaction that will lead to a new type of superfluid behavior among the ^3He atoms, a very special state of matter. We are now searching for this transition.

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Education:

This work, underway for a number of years, seeks to understand this mixture films system fully from the point of view of NMR and heat capacity measurements. A number of graduate students have been involved. Early work began with Jim Valles, now a professor at Brown University, continued with Donald Sprauge (now at Microsoft), continued with Peter Sheldon, (Associate Professor and Chairman, Randolf-Macon Women's College) and recently has involved a graduate student, John Cummings. Undergraduates have from time to time helped with the project and postdocs have received advanced training on it as well.

Societal Impact:

This work involves subtle interactions among atoms in a delicate two-dimensional environment. It teaches us about how these atoms interact in the absence of most perturbations. The experimental techniques involved are delicate and provide excellent training for young scientists. The techniques required in the low temperature environment provide excellent training for future work in the whole range of Condensed Matter sciences.